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OF

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# METHOD AND APPARATUS FOR MAKING LARGE-SCALE LAMINATED FOIL-BACK ELECTROLUMINESCENT LAMP MATERIAL, AS WELL AS THE ELECTROLUMINESCENT LAMPS AND STRIP LAMPS PRODUCED THEREFROM

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# METHOD AND APPARATUS FOR MAKING LARGE-SCALE LAMINATED FOIL-BACK ELECTROLUMINESCENT LAMP MATERIAL, AS WELL AS THE ELECTROLUMINESCENT LAMPS AND STRIP LAMPS PRODUCED THEREFROM

## Technical Field

The present invention relates generally to electroluminescent panels and deals more particularly with a method and related apparatus for continuous processing to produce large-scale foil-back electroluminescent lamp material. The invention further relates to split-electrode and parallel plate electroluminescent lamps and strip lamps made from the large-scale foil-back electroluminescent lamp material.

## Background of the Invention

Lamps and processes for making individual lamps from electroluminescent material are known in the electroluminescent (EL) lamp art. Typical EL lamps are relatively small in illuminated surface area and are known as "parallel plate lamps" that are produced from a number of processes including screen-printing, lamination and other processes known in the EL lamp art. The generic construction of most EL lamps can be described as being built up layer-by-layer from the front substrate having: 1) a transparent front substrate; 2) a transparent conductive front electrode; 3) a phosphor/organic binder layer; 4) a barium titanate layer and 5) a rear electrode layer formed from a conductive coating such as nickel acrylic or conductive silver ink.

An alternate generic construction uses an aluminum foil substrate to form the rear electrode, in which case there is no front substrate because the lamp is built up layer-by-layer from the rear. Also, in the generic construction described above a portion of the front electrode is not coated with the phosphor/organic binder layer and is left exposed to permit attachment of an electrical connector to the front electrode. Inherently, clear conductors are fragile and cannot support connection

and often a conductive ink, such as a silver ink, is used to support the termination and distribute the power applied thereto more evenly.

A disadvantage of EL lamps constructed as described above is the limited size or area that can be powered to maintain uniform brightness across the EL lamp. The transparent front electrode in these EL lamps is characteristically not a perfect conductor and exhibits a significant electrical resistance. This electrical resistance produces voltage drops that manifest as decreasing and lower relative brightness as the distance from the point of power connection increases. An EL lamp with a continuous silver conductor around its periphery is often used to obtain shorter connection distances to distribute current in a parallel plate EL lamp in an attempt to overcome the effects of voltage drops; however, the center of the EL lamp will become lower in brightness compared to the brightness at the periphery as the lamp area size increases.

*D'Onofrio* (U.S. Patent No. 4,534,743) discloses a process for continuously manufacturing flexible electroluminescent lamps by applying the materials throughout the course of the process on a carrier strip, which carrier strip itself becomes part of the lamp and wherein the termination method does not use the front electrode. In the '743 patent, the rear electrode is scored or "scribed" into two substantially equal areas so that the rear electrode areas are electrically isolated from each other. The terminations are then subsequently placed on the two rear electrode halves and connected to an AC voltage or power source. This type of construction is known as a "split-electrode" EL lamp construction and the two rear electrode areas function electrically as a voltage divider, therefore twice the normal operating voltage is required compared to a "parallel plate" EL lamp construction to achieve the equivalent brightness. The brightness, however, in a split-electrode EL lamp is obtained at a reduced current. The primary advantage of a split-electrode EL lamp compared to a parallel plate EL lamp is that most of the current, particularly for large surface area EL lamps, is distributed through the more conductive rear electrodes, which may be, for example, nickel acrylic paint or conductive silver ink. The front transparent electrode, typically indium tin oxide (ITO), carries a small

amount of the current, which only powers a local region of the EL lamp. The "split electrode" construction allows the fabrication of larger surface area EL lamps before any reduction in brightness occurs. A further advantage of the "split electrode" construction is the ability to utilize higher volume and automated manufacturing techniques, particularly web-to-web processing, than would otherwise be possible with other EL lamp constructions which are built to a given specification provided beforehand. That is, continuous rolls of EL lamp material can be coated using standard converting equipment, which provides the advantage that the specific lamp size does not have to be predefined prior to the manufacturing of a roll of EL lamp material.

U.S. Patent No. 5,019,748, assigned to the same assignee as the present invention, discloses a method for making an electroluminescent panel in a continuous fashion using a continuously moving carrier strip that becomes part of the electroluminescent panel or lamp to provide a highly reflective rear electrode that may be split in accordance with the "split-electrode" construction techniques described in U.S. Patent No. 4,534,743. The method described in the '748 patent for making the electroluminescent panel includes depositing a reflective metallic layer on a smooth finished surface dielectric layer to provide a highly reflective rear electrode. The high reflectivity is a result of controlling the smoothness gloss of the second cured dielectric adhesive layer which causes significantly increased reflectivity of light from the rear to the front of the lamp in operation. The carrier strip can then be coiled after the lamp layers are formed thereon for subsequent payout in a production line that may, for example, die cut lamp shapes from the coil and split the rear electrode. Attachment of electrical conductors to the split rear electrode areas is then made for example, as disclosed in U.S. Patent No. 5,045,755, assigned to the same assignee as the present invention. Although the '748 patent describes a method for making an EL lamp using an ultraviolet (UV) curable binder and electrostatic deposition of phosphor particles to provide an EL lamp that is superior to the EL lamp production methods and EL lamps of the prior art, the lamp produced in accordance with the method of the '748 patent is not

entirely satisfactory. The EL lamp produced in accordance with the '748 patent requires two separate coating and curing operations for the binder to encapsulate the phosphor particles, which are electrostatically deposited in a separate operation and a further third coating and curing operation to add a rear electrode. The structure thus produced is more costly than it need be resulting from the numerous separate operations required to produce the EL lamp material. Additionally, the EL lamp so manufactured has some performance limitations as well. These limitations may be manifested as lower total brightness resulting from a thick second binder coating and lack of rear barium titanate to impedance layer, and limited overall total size due to limited conductivity of the rear electrode.

Accordingly, it is an object of the present invention to reduce the cost of manufacturing EL lamp material by reducing the number of process steps in production.

It is a further object of the present invention to improve the performance of the EL lamp itself made from the EL lamp material by increasing its brightness and substantially removing limitations in the size or surface area of an EL lamp.

It is yet a further object of the present invention to provide apparatus for the continuous production of two primary substrates that are laminated together to create the large-scale foil-back EL lamp material in continuous rolls.

It is a still further object of the present invention to provide an improved foil-back EL lamp material and an EL lamp that reduces the time to make a product by eliminating registration and artwork requirements.

It is an additional object of the present invention to provide an EL lamp material that facilitates handling and is capable of "split-electrode," "parallel plate," and "special effect" EL lamp construction.

It is a yet further object of the present invention to provide an EL lamp of a desired arbitrary size and shape to be cut from a continuous roll of EL lamp material.

Summary of the Invention

In a broad aspect, the invention relates to a method for continuously manufacturing EL lamp material. The method includes coating an indium tin oxide polyester film (ITO/PET) substrate with a layer of phosphor particulate embedded in an organic binder defining a front substrate, coating an aluminum foil polyester film laminate with a layer of barium titanate defining a rear substrate, and then continuously laminating the front substrate and the rear substrate with the organic binder phosphor particulate layer facing the barium titanate layer to produce an EL lamp laminate material having an ITO front electrode and an aluminum foil rear electrode.

The method further includes coating the ITO surface of the ITO/PET substrate with a UV-curable organic binder prior to electrostatically depositing a layer of phosphor particulate on the UV-curable organic binder surface wherein the phosphor particulate is partially embedded in the organic binder. The UV-curable organic binder phosphor particulate layer is then set to a predetermined desired thickness.

The method further includes curing the UV-curable organic binder phosphor particulate layer prior to laminating the front and rear substrates.

The method further includes partially curing the UV-curable organic binder phosphor particulate layer prior to setting the thickness of the layer.

The method alternatively includes coating the ITO surface of the ITO/PET substrate with a slurry mixture of a UV-curable organic binder and phosphor particulate and then setting the thickness of the UV-curable organic binder and phosphor particulate layer to a predetermined desired thickness.

Further, the UV-curable organic binder phosphor particulate layer is cured prior to the step of laminating the front and rear substrates or the UV-curable organic binder phosphor particulate layer may be wet and cured after the step of laminating the front and rear substrates. Exposed portions of the phosphor particulate extending beyond the surface of the organic binder are fully covered and embedded in the barium titanate layer during the laminating process.

The thickness of the EL lamp laminate material is set to a predetermined desired thickness during lamination of the front and rear substrates.

The method alternatively includes coating the ITO surface of the ITO/PET substrate with a thermoplastic clear organic binder which is set to a predetermined desired thickness. The thermoplastic organic binder layer is warmed to soften it and then a layer of phosphor particulate is electrostatically deposited on the softened thermoplastic organic binder surface. The thermoplastic organic binder phosphor particulate layer is chilled to firm it on the ITO/PET substrate prior to laminating it with the rear substrate.

A further aspect of the invention relates to apparatus for continuously manufacturing EL lamp laminate material. The apparatus includes means for coating a continuous coil of an indium tin oxide polyester film (ITO/PET) substrate with a layer of an organic binder; means for depositing phosphor particulate on the organic binder, wherein the phosphor particulate organic binder coated ITO/PET substrate defines a front substrate; means for coating a continuous coil of an aluminum foil polyester film with a barium titanate layer, wherein the barium titanate coated aluminum foil polyester film defines a rear substrate; and means for laminating the front substrate and the rear substrate with the organic binder phosphor particulate layer facing the barium titanate layer to produce an EL lamp laminate material having an ITO front electrode and an aluminum foil rear electrode.

The ITO/PET coating means further includes a gravure roller for direct or indirect application of the organic binder layer to the ITO surface. The organic binder may be a UV-curable organic binder.

The phosphor particulate depositing means further includes electrostatic depositing means. A calender roll is used to set the thickness of the front substrate to a predetermined desired thickness.

Alternatively, the ITO/PET coating means may be a knife-over-roll apparatus for applying a slurry mixture of a UV-curable organic binder and phosphor particulate to the ITO surface.

The UV-organic binder curing means may be located prior to or after the laminating means. The laminating means includes a pressure-nip laminator or a heated-nip laminator.

A further aspect of the invention relates to a method for continuously manufacturing EL lamp material. The method includes providing a continuous roll of an indium tin oxide coated polyester film ITO/PET substrate of indeterminate length and width. The indium tin oxide surface of the ITO/PET substrate is coated with a UV-curable organic binder layer and a layer of phosphor particles is deposited in the UV-curable organic binder. The phosphor particle UV-curable organic binder layer is partially cured and set to a predetermined desired thickness. The UV-curable organic binder phosphor particle layer is cured, wherein the ITO/PET cured organic binder phosphor particle substrate defines a front electrode substrate. A continuous roll of an aluminum foil polyester film laminate of indeterminate length and having a width substantially equal to the width of the ITO/PET substrate has the aluminum foil surface coated with a barium titanate layer, wherein the barium titanate coated aluminum foil polyester film laminate defines a rear electrode laminate. The front electrode laminate and the rear electrode laminate are continuously joined with the organic binder phosphor particle layer facing the barium titanate layer to produce a continuous roll of EL lamp laminate material.

Further, foreign matter is removed from the indium tin oxide surface prior to coating with the UV-curable organic binder layer. The UV-curable organic binder layer is coated onto the indium tin oxide surface by direct or indirect gravure coating.

The UV-curable organic binder layer is coated with a thickness in the range of about 0.3 mils to 0.8 mils.

A layer of phosphor particles of like electrical polarity charge is electrostatically deposited onto the surface of the UV-curable organic binder layer and then discharged after being applied.

The phosphor particles deposited have a microencapsulated inorganic coating, preferably aluminum oxide. The thickness of the UV-curable organic binder phosphor particle layer is set by passing the partially cured organic binder phosphor particle coated ITO/PET substrate through at least one calender roll. The calender roll is heated to soften the partially cured organic binder to more easily reposition the phosphor particles.

Preferably, coating the UV-curable organic binder includes coating with a clear, UV-curable organic binder, wherein the organic binder is moisture resistant and has a dielectric constant in the range of about greater than 4, a dissipation factor in the range of about less than 0.125, and a dielectric strength in the range of about 1000 +/- 200 volts per mil.

The front and rear electrodes are continuously joined by passing the front and rear electrodes through a nip laminator, which may be a heated nip laminator.

Preferably, the rear electrode laminate is cut into pairs of parallel strips prior to continuous joining with the front electrode laminate to produce a continuous roll of split-electrode EL lamp laminate material.

A further aspect of the invention relates to an electroluminescent (EL) lamp material having a front electrode laminate comprising an indium tin oxide layer coated on a polyester film, an organic binder layer coated on the indium tin oxide layer and a layer of phosphor particles deposited on the organic binder layer; a rear electrode laminate comprising an aluminum foil polyester film and a barium titanate layer coated on the aluminum foil; and a laminate of the front electrode laminate and the rear electrode laminate with the organic binder layer facing the barium titanate layer to form the EL lamp laminate material. The organic binder is a UV-curable organic binder and the organic binder phosphor particle layer is set to a predetermined thickness prior to laminating the front and rear electrode laminates. The EL lamp material is cut to a desired arbitrary size and shape and further comprises the rear electrode cut to a predetermined depth through the aluminum foil polyester film and partially into the barium titanate layer to produce a split-electrode EL lamp having at least two electrically isolated rear electrode areas. Each of the at

least two electrically isolated rear electrode areas have an electrical connector in contact with the aluminum foil for powering the EL lamp.

Preferably, the isolated rear electrode areas are of substantially equal area to emit light of substantially equal brightness and are of unequal area to emit light of unequal brightness. The rear electrode may have multiple pairs of rear electrode areas for special effect lighting.

Alternatively, the EL lamp material is cut to a desired arbitrary size and shape and further comprises the laminate having dual scribe lines along a marginal peripheral region cut to predetermined depths through the laminate, wherein the first of the dual scribe lines is outward of the dual scribe lines and is cut completely through the rear electrode laminate and the phosphor particle organic binder layer terminating at the indium tin oxide layer, and the second of the dual scribe lines is cut to a predetermined depth through the aluminum foil polyester film and partially into the barium titanate layer to produce a parallel-plate EL lamp.

Preferably, the laminate region between the first scribe line and the laminate outer peripheral edge further includes an electrical connector through the laminate and in electrical contact with the indium tin oxide for powering the front electrode defining one plate of the parallel plate EL lamp.

Preferably, the laminate region between the second scribe line and the laminate outer peripheral edge opposite the laminate outer peripheral edge outward of the first scribe line further includes an electrical connector through the laminate and in electrical contact with the aluminum foil for powering the rear electrode defining the other plate of the parallel plate EL lamp.

Preferably, the first scribe line is flooded with a conductive material.

## Brief Description of the Drawings

Other features, benefits and advantages of the present invention will become readily apparent from the following written description of several preferred embodiments taken in conjunction with the drawings wherein:

Fig. 1 is a schematic illustration of apparatus for continuous production of the electroluminescent panel of the present invention.

Figs. 2A-2C are a series of somewhat schematic cross-sections through the width of the front substrate of the EL lamp material as the operative layers are added on one another.

Figs. 3A and 3B are a series of somewhat schematic cross-sections through the width of the rear substrate of the EL lamp material as the operative layers are added on one another.

Fig. 4 is a somewhat schematic cross-section through the widths of the front and rear substrates of the EL lamp material as it might appear entering and leaving the laminating nip.

Fig. 5 is a schematic illustration of a heat and pressure nip roller assembly for laminating the front and rear substrates to form the electroluminescent panel base material.

Fig. 6 is a schematic illustration of apparatus for coating a layer of barium titanate on the aluminum foil surface of the rear substrate.

Fig. 7 is a schematic illustration of an alternate apparatus for the continuous production of the electroluminescent panel of the present invention.

Fig. 8 is a schematic illustration of a further alternate apparatus for the continuous production of the electroluminescent panel of the present invention.

Fig. 9 is a schematic illustration of a further alternate apparatus for the continuous production of the electroluminescent panel of the present invention.

Fig. 10 is a schematic illustration of a yet further alternate apparatus for the continuous production of the electroluminescent panel of the present invention.

Fig. 11 is a schematic illustration of an alternate lamination process to produce a coil of split-electrode construction EL lamp material without scribing.

Fig. 12 is a cross-section view of a finished split-electrode EL lamp cut from a continuous roll of EL lamp material made in accordance with the present invention showing the scribe line and electrical connectors.

Fig. 13 is a plan view of the back of a finished split-electrode EL lamp made in accordance with the present invention showing the scribe line and electrical connectors.

Fig. 14 is a plan view of the back of a finished split-electrode EL lamp made in accordance with the present invention showing the scribe line off-center and electrical connectors to produce special effects.

Fig. 15 is a plan view of the back of a finished parallel-plate EL lamp made in accordance with the present invention showing dual off-center scribe lines and electrical connectors.

Fig. 16 is a cross-section view of a finished parallel-plate EL lamp cut from a continuous roll of EL lamp material made in accordance with the present invention showing off-centered scribe lines and silver ink connection through one scribe line to the front electrode.

Fig. 17 is a schematic perspective view of an electrical connector of the type that may be used in the present invention.

Fig. 18 shows the electrical connector of Fig. 17 with the connector leg ends bent to provide gripping attachment to the EL lamp.

Fig. 19 is a plan view of an alternate embodiment of a finished parallel-plate EL lamp showing multiple dual-scribe lines.

Fig. 20 is a plan view of a further alternate embodiment of a finished parallel-plate lamp having dual-scribe lines located along the back surface marginal peripheral edge region.

Fig. 21 is a plan view of an array of EL lamp rear electrodes made from multiple scribe lines to produce special effect lighting.

## Detailed Description of Preferred Embodiments

Turning now to the drawings and considering the invention in further detail, a general overview of the large-scale laminated foil-back EL (electroluminescent) panel lamp and associated methods for construction of such EL lamps embodying the present invention is presented to enable the reader to gain a fuller understanding

of the exemplary embodiments of the invention. Broadly, the large-scale laminated foil-back EL panel lamp of the present invention has two substrates, referred to for purposes of explanation as a front substrate and rear substrate, which are coated separately and then laminated together as described in further detail herein. The present invention provides additional improvements, features and benefits over the EL lamps and their construction and manufacture as disclosed in U.S. Patent Nos. 4,534,743, 5,019,748 and 5,045,755 the disclosures of which are hereby incorporated by reference. In the description which follows, like parts and elements have like reference numerals.

Fig. 1 illustrates schematically apparatus for the continuous processing of the EL basic panel material components into long coils or rolls of indeterminate length. In Fig. 1, the front substrate is provided as a continuous carrier strip **10** of indium/tin oxide coated polyester (ITO/PET), which is conveniently stored on a payoff reel **12**. Preferably, the front substrate is polyester (PET) coated with a clear conductive coating such as indium tin oxide (ITO), but other substrates and other conductive coatings now known or future developed that provide the desired characteristics and properties may be used. Preferably, the ITO/PET carrier strip has light transmission greater than 80-85% and sheet resistance in the 100-500 ohms per square inch range. A schematic cross-section of the ITO/PET carrier strip **10** is shown in Fig. 2A, wherein the polyester transparent front substrate is designated **100** and the indium/tin oxide layer coated on the polyester is designated **102**.

Uncoiling means well known to those in the machine process art are provided to uncoil the ITO/PET carrier strip **10** from the reel **12** and drive it through a series of guidance strip alignment rolls **14** and tension adjustment controls **16** and ultimately as the front substrate is laminated with the rear substrate to coil the EL laminate material on a take-up reel **18** at the other end of the line. A conventional motor drive (not shown) continuously moves the ITO/PET carrier strip **10** at a substantially continuous speed in the range of about 10 to 80 feet per minute, which speed may be selected in accordance with the presently known component materials and processing techniques and preferably is in the 30 to 60 feet per minute

range. It will be understood that the speed may be slower or faster than that stated for other EL component materials now known or future-developed. The width of the ITO/PET carrier strip **10** may be in the range of 6 inches to 55 inches, and the length can be as long as the limits of the material processes allow. For example, the ITO/PET carrier strip **10** currently has an upper limit on length with no splices or ITO coating irregularities of approximately 1800 to 2000 feet, with a more typical length of 1200 feet. It is expected that as ITO coating processes improve, the upper limit length of the ITO/PET carrier strip **10** will also increase. Additionally, the width of the ITO/PET carrier strip **10** may increase for different EL component materials now known or future developed. The EL component materials allow, together with different processing equipment now known or future developed, the manufacture and processing of larger width EL laminate material.

The ITO/PET carrier strip **10** moves continuously from the payoff reel **12** through a commercially available web cleaner generally designated **20** to remove random foreign matter and lint from the ITO/PET strip surface. When the coating cycle is turned on, the ITO/PET carrier strip **10** advances past a gravure coating station, generally designated **30**, wherein a UV curable clear organic binder **104** is continuously coated on the ITO face side **10a** of the ITO/PET carrier strip **10**. Preferably, the UV-curable organic binder is a custom-synthesized material with exacting properties. The UV-curable organic binder must be clear, have a relatively high dielectric constant (preferably greater than 4.0 at the lower end for best results), have a relatively low dissipation factor (preferably less than 0.125), have a relatively high dielectric strength (preferably 1000 volts/mil, but typically 800 to 1200 volts/mil), have good adhesion, and must be moisture resistant. Obviously, these parameters may change as new materials and processes are developed.

The gravure coating station **30** may utilize any appropriate technique or equipment now known or future developed to apply the UV curable organic binder. In one preferred embodiment, the organic binder is pumped up to a coating head **32** and applied onto the ITO face surface **10a** when the binder achieves the necessary operating temperature. The binder is a 100% solids UV-curable material whose

viscosity is too high to use at room temperature and is therefore heated to the range of 100°F to 130°F to lower its viscosity. The coating head **32** is a gravure coating head and can be used in either a direct gravure or offset gravure coating mode. In the direct gravure coating method (not shown in Fig. 1), the organic binder **104** is coated directly onto the ITO face surface **10a** of the carrier strip **10** to a thickness of 0.3 to 0.8 mils (0.0003 inches to 0.0008 inches). An offset gravure coating method is illustrated in Fig.1 wherein the organic binder **104** is coated onto an intermediate roll **34** that then transfers the organic binder coating to the gravure coating head **32** which in turn applies the coating onto the ITO face surface **10a**. The added transfer step of the offset gravure method smoothes out any pattern caused by the individual cells on the gravure coating head surface. Depending on the flow-out characteristics of the binder and the line speed, this added transfer step may or may not be needed. A pressure roller **36** forms a nip **38** with the gravure coating head **32** through which nip the carrier strip **10** passes to receive the organic binder coating layer. A schematic cross-section of the UV clear organic binder coated ITO/PET carrier strip **10** is shown in Fig. 2B, wherein the UV clear organic binder layer is designated **104** and is shown applied to the surface **102a** of the ITO layer **102**.

The organic binder coated ITO/PET carrier strip moves from the gravure coating station **30** to a phosphor depositing station generally designated **40** with the carrier strip substantially parallel with the ground, and with the UV organic binder coating face surface **10b** facing in a downward direction. The phosphor depositing station **40** is preferably an electrostatic phosphor particulate depositing station which includes a source or pan **46** of dry phosphor particulate powder or particles **106**. The phosphor powder is a commercially available EL phosphor with a microencapsulated inorganic coating such as aluminum oxide or aluminum nitride. The pan **46** is connected to a voltage source **48** to make the pan positive relative to the ITO/PET carrier strip which is held at substantially ground potential through contact with grounded guide rollers **14** and contact with a grounding plate **44** located directly above the dry phosphor particulate source **46**. The electrostatic phosphor particulate depositing station **40** is designed to place a complete monolayer of

phosphor particulate onto the wet (uncured) UV organic binder coating face surface **10b**. The phosphor particulate powder is propelled in a cloud towards the UV binder coated ITO/PET strip in the presence of a high voltage electric field developed between the pan **46** and the ITO/PET carrier strip. The result of this action is to impart each phosphor particle with a like charge as it moves through this electric field. The charged phosphor particles will tend to avoid stacking on top of each other due to the repulsion of like charges and find exposed or uncovered areas on the UV binder coated ITO/PET surface. The charge on the deposited phosphor particles then bleeds through the UV organic binder to the ITO/PET carrier strip, which is at substantially ground potential due to the strip's contact with the rollers **14** and the grounding plate **44**.

The ITO/PET carrier strip with the phosphor coated wet UV organic binder face surface shown generally as **10c** leaves the phosphor depositing station **40** and moves through a UV curing station shown generally as **60**. Upon exiting the electrostatic deposition chamber, there is approximately a monolayer of phosphor particles partially embedded in the UV curable organic binder. A schematic cross-section of a UV curable organic binder coated ITO/PET strip with a layer of phosphor particles **106** is shown in Fig. 2C wherein the partially embedded phosphor particles project unpredictable distances beyond the surface **108** of the UV curable organic binder layer **104**. The UV curing station **60** includes a UV source **62** which has adjustable variable power levels for partially curing the organic binder to firm it up to allow the further embedding of the phosphor particles **106**. The process of depositing and further embedding the phosphor particles is referred to generally as a phosphorlayorset process that does not tear out or fracture the phosphor particles that are delicate but, rather, sets the phosphor-organic binder layer to a desired thickness. Upon exiting the UV curing station **60**, the ITO/PET carrier strip passes through a phosphor-organic layer thickness setting station **70** having at least one calender roll **72** which presses against the projecting phosphor particles **106** and forces them deeper into the organic binder and substantially even in height with the other phosphor particles in the mono-layer. The UV curing

station **60** also includes a heater **64** that directs controlled heat at the ITO/PET carrier strip to soften the phosphor-organic binder layer in preparation for its further processing in the layer thickness setting station **70**. During processing at the station **70**, the partially cured phosphor-organic binder face **10d** surface of the ITO/PET carrier strip is in contact with the outer peripheral surface of the calender roll **72** which preferably is a thermostatically heat controlled, ceramic finished drum to maintain the phosphor-organic binder layer at a desired temperature. The PET side **10e** of the ITO/PET carrier strip opposite the partially UV cured phosphor-organic binder layer face **10d** surface passes through three highly polished rollers **74, 76, 78** spaced along the outer peripheral surface of the drum **72** and which are set at successive heights. The first roller **74** is set to obtain the largest thickness, the second roller **76** is set to obtain a smaller thickness than the first roller **74** but not as thin as the thickness obtained by the setting of roller **78**. The result is the phosphor-organic binder layer is set at the proper desired thickness while avoiding harm to the phosphor particles. Quite naturally, in the final assembly of EL lamps that achieve the required quality of EL lamps, maintaining the proper height of the phosphor layer is critical. Upon exiting the layer thickness setting station **70**, the ITO/PET carrier strip with the phosphor-organic binder layer shown generally as **11** passes through a second UV curing station **80** to fully cure the phosphor-organic binder layer. The fully cured phosphor coated ITO/PET carrier strip designated generally **15** is generally referred to as the front substrate wherein the UV cured organic binder phosphor side is designated **15a** and the PET side is designated **15b** and can be coiled and stored for future use or can continue on as illustrated in Fig.1 for lamination with a rear substrate to form the basic EL lamp material as described below.

In both the application of the UV curable clear organic binder layer **104** and the electrostatic deposition of the phosphor particles **106** on the ITO/PET carrier strip, the organic binder and phosphor particles are coated continuously and uniformly across the surface of the entire width and length of the ITO/PET carrier

strip without surface patterning of the deposits, that is, the deposited surface is smooth.

The rear substrate is a polymer film barium titanate coated aluminum foil laminate designated generally as **200** in Fig.1 and is conveniently stored on a payoff reel **92**. Preferably, the aluminum foil is type 1145-0 wherein "1145" identifies the foil as 99.45% aluminum and "0" identifies the foil as being "dead soft." Preferably, the aluminum foil has a thickness in the range of 0.001 inches. Preferably, the polymer film is commercial grade polyester (PET) and has a thickness in the range of 0.002 inches. A schematic cross-section of the aluminum foil/PET laminate **230** is shown in Fig. 3A wherein the aluminum foil is designated **204** and the polyester film is designated **202**. The active element is the aluminum foil **204**, which forms the EL lamp's rear electrode as explained below. The polyester film **202** is laminated to the aluminum foil **204** for two reasons. First, the laminate allows the processing of the aluminum foil **204** more easily because the polyester film **202** prevents the aluminum foil from tearing and creasing, which the aluminum foil is likely to do during the coating and other operations. Second, the polyester film **202** serves as an insulator for the rear electrode of an operating EL lamp to prevent accidental electrical shock when the EL lamp is powered. The laminate **230** also provides an excellent moisture barrier for the lamp with a one-mil thickness of aluminum foil being considered to be pinhole-free and essentially hermetic. Fig. 3B shows a schematic cross-section of a barium titanate coated aluminum foil/PET laminate wherein the barium titanate layer designated **206** is coated on the aluminum foil face surface of the laminate **230**.

The UV cured ITO/PET phosphor particle embedded laminate defining the front substrate **15** and the barium titanate coated aluminum foil/PET laminate **200** defining the rear substrate are laminated together with the barium titanate coating layer **206** facing the organic binder phosphor particle coating layer **15a** as shown in Fig. 4. The front and rear substrates are continuously laminated together in a heated-nip laminating station, generally designated **210** in Fig. 1, under heat and pressure using unwind and rewind equipment (not illustrated). Preferably, the nip

temperature is in the range of approximately 250 to 350 degrees Fahrenheit. Preferably, the nip pressure is in the range of approximately 50 to 100 pounds per lineal inch. The barium titanate layer is designed to flow around the exposed top of each phosphor particle and completely embed it during the laminating step. As a result, the total thickness of the finished EL lamp laminate is thinner than the measured thickness of the sum of each of the front and rear coated substrates. Fig. 5 is a schematic illustration of a representative embodiment of the heated-nip laminating station **210** wherein rollers **214** and **216** are positioned and arranged for relative movement to one another and form a nip **212** into which the front substrate and rear substrate are fed. The rollers **214** and **216** are arranged to provide pressure to the front and rear substrates as they continuously pass through the rollers to join the front and rear substrates to form the EL lamp laminate material. Preferably, one or both of the rollers **214, 216** are heated.

Fig. 6 is a schematic illustration of an apparatus generally designated **250** for applying a coating of barium titanate/organic binder mixture **220** to the aluminum foil face surface **208** of the aluminum foil/PET laminate **230**. The barium titanate/organic binder mixture **220** is contained in a hopper **252** of a knife-over-roll coat or reverse-roll coat depositing station **254**. The barium titanate/organic binder mixture **220** is applied to the surface face **208** of the aluminum foil/PET laminate **230** as the laminate moves through the depositing station **254**. The barium titanate/organic binder mixture **220** is coated as a solvent slurry with a viscosity of approximately 800 centipoises at 75°F and cured in a drying oven (not shown in Fig. 6). Solvent vapors **222** are exhausted during the drying process. The organic binder has a number of specific properties and can be, acrylic, polyvinylidine fluoride (PVDF) or other fluorinated or thermoplastic polymers. The characteristics required for the organic binder are a high dielectric constant, high dielectric strength, good moisture barrier properties, good adhesion and thermoplastic. The organic binder and barium titanate are coated continuously and uniformly across the entire width and length of the web of the laminate **230**. As in the case of the front substrate, there is no patterning of the deposits on the foil surface face.

The barium titanate organic binder layer has several functions among other functions in the finished EL lamp primarily however: 1) acting as a voltage impedance layer to prevent voltage breakdown between the front and rear electrodes; 2) acting as a heat-seal adhesive layer for laminating the front and rear substrates together; 3) acting as a diffuse reflector behind the light emitting phosphor layer, and 4) acting as a moisture barrier layer to reduce or minimize moisture transmission to the phosphor particles.

It will be apparent that one advantage of the method of the present invention is there are no registration issues during the lamination process, other than alignment of the two substrates to maximize yield. The front and rear substrates thus laminated create a continuous coil of base EL lamp material **218** which is uniform and continuous across the entire width and length of the web. As illustrated in Fig. 1, the continuous coil of EL lamp material **218** is wound on the take-up reel **18**. Again, the upper limit on length with no splices or ITO coating irregularities is approximately 1800 to 2000 feet. As processing methods improve, the length of the base EL lamp material will increase.

Although the apparatus of Fig. 1 contemplates the rear substrate is preformed as a barium titanate coated aluminum foil/PET substrate, the aluminum foil/PET substrate can be coated as part of the process using apparatus similar to that shown in Fig. 6 located prior to the laminating station **210**.

Turning now to Fig. 7, alternate apparatus particularly suitable for the production of smaller volumes of electroluminescent panels is schematically illustrated therein and generally designated **150**. In Fig. 7, the front substrate is provided as a continuous carrier strip **180** of indium/tin oxide coated polyester (ITO/PET) substantially identical to the ITO/PET carrier strip described in conjunction with Fig. 1. The ITO/PET carrier strip **180** is conveniently stored on a payoff reel **152**. Uncoiling means are provided to uncoil the ITO/PET carrier strip **180** from the reel **152** and drive it through a series of guidance strip alignment rollers **154** and tension adjustment controls **156** and ultimately as the front substrate is laminated with the rear substrate to coil the EL laminate material **240** on a take-up

reel **158** at the other end of the line. A conventional motor drive (not shown) continuously moves the ITO/PET carrier strip **180** from the payoff reel **152** through a commercially available web cleaner, generally designated **160**, to remove random foreign matter and lint from the ITO/PET strip surface. The ITO/PET carrier strip **180** advances from the web cleaner **160** to a knife-over-roller deposition station, generally designated **170**. A slurry of phosphor particles in an uncured UV organic binder is contained in a slurry reservoir **172**, which also includes a mixer (not shown) to maintain as uniformly as possible a distribution of the phosphor particulate in the slurry. The slurry of phosphor particulate and uncured UV binder is delivered to the knife-over-roller deposition station **170**, which includes a roller **174** and a knife **176** having an edge **178** positioned to provide the desired layer thickness of the phosphor particulate and UV binder mixture on the ITO face surface **182**. The knife edge **178** "wipes" the excess slurry delivered to the ITO surface **182** by the slurry applicator head **173**. The phosphor particulate and UV-binder-coated ITO surface **184** passes through one or more UV curing stations **186** and **190**, each disposed on opposite sides of the carrier strip. The UV curing stations **186, 190** each include a UV source **188, 192**, respectively, to cure the phosphor particulate UV binder layer. The cured phosphor UV binder layer ITO/PET carrier strip **194** moves to a heated nip lamination station generally designated **270**. The rear substrate generally designated **200** comprises a laminate made of an aluminum foil generally designated **202**, a polyester film **204** and a barium titanate layer **206** as described above in connection with Fig. 1. The rear substrate is conveniently stored on a payoff reel **92** and is fed to and through a nip **272** formed between rollers **274, 276**. Preferably, one of the rollers **274, 276** is a heated roller and the front and rear substrates are continuously laminated together under heat and pressure using unwind and rewind equipment (not illustrated) in a similar manner as described above in connection with Fig. 1. The front and rear substrates are laminated with the barium titanate layer **206** face-to-face with the phosphor particulate UV binder layer **184**. The resulting EL laminate lamp material **240** is coiled and wound on the take-up reel **158**.

Turning now to Fig. 8, a further alternate apparatus for the continuous production of electroluminescent panels is schematically illustrated therein and generally designated **300**. The apparatus **300** is similar to the apparatus **150** of Fig. 7 and like parts have like reference numerals. The front substrate has a slurry of UV organic binder and phosphor particulate applied to the ITO side **182** of the ITO/PET carrier strip **180** and is wet as it moves past the knife-over-roll deposition station **170**. If a solvent is used to lower the viscosity of the slurry, then the solvent is dried by passing the coating through an in-line oven shown in the dashed line box **302**. The wet slurry coated ITO/PET strip is immediately laminated to the rear substrate **200** under pressure only in a pressure laminating station generally designated **310**. The barium coated aluminum foil PET strip **200** is made as described above and enters the nip **312** of the pressure laminating station **310** with the barium coated side **206** of the rear substrate facing the wet UV organic binder phosphor particulate slurry side **184** of the front substrate. The nip **312** is formed by rollers **314, 316** adjustably spaced relative to one another to provide the desired laminating pressure and EL lamp laminate thickness. The thus laminated front and rear substrates now pass through a UV curing station generally designated **320** which is positioned on the front or ITO face side **262** of the laminate to cure the UV organic binder and produce the EL lamp laminate material **260**. The base EL lamp material **260** is coiled on the take up reel **158** and may be stored for future use as described above.

Turning now to Fig. 9, an alternate apparatus for the continuous production of electroluminescent panel is schematically illustrated therein and generally designated **350**. The apparatus **350** is similar to the apparatus illustrated in Fig. 1 in that phosphor particulate electrostatically deposited on the front substrate is then laminated with the rear substrate as discussed in connection with Fig. 1, and accordingly like parts have like reference numerals. The front substrate is provided as a continuous carrier strip **10** of ITO/PET from a payoff reel **12**. The ITO/PET carrier strip **10** uncoils from the reel **12** through a series of tension adjustment controls **16**. The carrier strip **10** then passes through a web cleaner (not shown) to

remove any debris or particulate from the surface prior to entering a knife-over-roll coating station, generally designated **360**, wherein a thermoplastic clear organic binder is pumped from a storage reservoir **362** to an applicator head **364**, which applies the binder to the ITO surface side **10a** of the carrier strip **10**. The height of the edge **366** of the knife **368** is adjusted to provide the desired layer thickness of the binder on the ITO face as the carrier strip moves between the knife edge **366** and the roller **370**. If a solvent is used to lower the viscosity of the binder, the solvent is dried by passing the coated carrier strip through an in-line oven illustrated by the dashed-line box **374**. The thermoplastic clear organic binder coated carrier strip is then preheated to a desired predetermined temperature by the heater **376** prior to the carrier strip entering the electrostatic phosphor particulate depositing station **40**. The heater **376** softens the thermoplastic clear organic binder upon which a layer of phosphor particulate **106** is electrostatically deposited as the carrier strip moves through the electrostatic deposition station **40**, which operates as discussed above in connection with Fig. **1**. Upon exiting the electrostatic deposition station **40**, the phosphor particulate coated thermoplastic clear organic binder and carrier strip forming the front substrate **390**, passes over a conventional chill roll **378** to firm the phosphor organic binder layer. The firmed front substrate **392** moves to a heated nip lamination station, generally designated **210**. The barium titanate coated aluminum foil/PET rear substrate **200** is fed from a payoff reel **92** and enters the nip **212** formed by the rollers **214, 216** with the phosphor coated thermoplastic clear organic binder side **394** of the front substrate **392** facing the barium titanate side **206** of the rear substrate **200** as the front and rear substrates enter the nip **212**. The front and rear substrates are continuously laminated together in the heated nip laminating station **210** as described above in connection with Fig. 1 to form the EL panel lamp material **396**, which is coiled on the take-up reel **18** and may be stored for future use as described above.

Turning now to Fig. 10, an alternate apparatus for the continuous production of electroluminescent panel is schematically illustrated therein and generally designated **400**. The apparatus **400** is similar to the apparatus illustrated in Fig. 1

and the front substrate **15** is constructed substantially identically to that described in Fig. 1, and therefore like parts have like reference numerals and operate in substantially identical fashion to that described above in connection with Fig. 1. The basic difference between the apparatus **400** of Fig. 10 and that of Fig. 1 is that the aluminum foil/PET rear substrate is processed in a different manner. In Fig. 10, the aluminum foil/PET carrier strip **430** is stored on a payoff reel **402** and is uncoiled using conventional uncoiling means (not shown in Fig. 10) to advance the aluminum foil/PET carrier strip **430** through a series of tension adjusting controls **404** to a barium titanate coating station, generally designated **420**. The aluminum foil/PET carrier strip **430** is substantially identical in construction to the carrier strip shown in Fig. 3A. The aluminum foil side **430a** faces upward in the figure and is coated with a mixture of barium titanate and UV curable organic binder, which is stored in a reservoir **422**. The barium titanate UV curable organic binder mixture is applied to the surface **430a** by means of an applicator head **424**. The depositing station **420** is a knife-over-roll apparatus and comprises a knife **426** having an edge **428** adjustably positioned at a distance from the surface **430a** as the foil/PET carrier **430** passes over the peripheral outer circumferential surface of a roller **406** to provide the desired layer thickness of the barium titanate UV curable organic binder mixture on the aluminum foil. Although a knife-over-roll apparatus is illustrated, any suitable method, such as a reverse roll coat, may also be utilized to provide the desired layer thickness of the barium titanate UV curable organic binder mixture. If a solvent of some type is used to lower the viscosity, then the solvent is dried by passing the coating through an in-line oven, generally designated by the dashed-line box **410**. The wet barium titanate organic binder coated rear substrate **430b** moves in a continuous fashion to a pressure laminating station, generally designated **440**, into a nip **442** formed by rollers **444, 446**. The rear substrate with the barium titanate UV curable organic binder layer **430b** is laminated with the front substrate **15** with the wet barium titanate UV curable organic binder layer facing the phosphor organic binder side **15a** of the front substrate **15** as the rear and front substrates pass through the pressure nip **442**. As the front and rear substrates move through the nip

**442**, the barium titanate UV curable organic binder mixture surrounds any phosphor particulate extending beyond the surface of the organic binder of the front substrate. The thus laminated rear and front substrates pass a UV curing station, generally designated 448, wherein the barium titanate UV curable organic binder is fully cured. The fully cured EL lamp laminate material **432** is then wound on the take-up reel **18** as previously described.

The completed coil of base EL lamp material made in accordance with any of the above-discussed methods is now ready to be fabricated into specific customer applications. A benefit of the process of the EL electroluminescent panel lamp material of the present invention is that the EL panel lamp material can be fabricated prior to knowing the specific customer size or shape requirements of the completed EL lamps. The roll of EL panel lamp material contains large surface areas from which customers on their own and in their own design can use devices as simple as scissors or by complex high production tooling devices to remove individual lamps from the basic EL panel lamp material. Once a customer's requirements are known, the basic or "raw" EL lamp material coil can be cut up using standard slitting and sheeting operations to match the customer's required dimensions. The pieces of the "raw" EL lamp material so cut will then have the rear foil electrode parted in a process called "scribing," after which an electrical terminal is applied to each side of the scribed polyester to complete the construction of an active split-electrode EL lamp. Alternate construction and terminal connection methods embodying the present invention are described below.

In an alternate embodiment of the invention as illustrated schematically in Fig. 11, one or more coils of split-electrode EL lamp material can be fabricated as part of the EL laminate lamp material construction. Figure 11 illustrates the barium titanate organic binder coated FOIL/PET substrate **200** passing cutting means, generally designated **460**, comprising one or more knife edges **462, 464, 466** positioned parallel to one another and substantially perpendicular to the substrate **200**. The cutting means **460** is located immediately prior to the laminating station **210** and cuts or slits the rear substrate into strips **450, 452, 454, 456** of pre-defined

widths. These strips are then laminated in pairs or multiple pairs, under heat and pressure in the nip-heated laminating station **210** as discussed in connection with Fig. 1. The lamination process is carried out with extreme precision to maintain a separation of 0.006 inches to 0.012 inches between the strips. Once the laminating process is completed, the laminated pairs are slit into narrower strips by cutting means generally designated **470** made up of one or more knife edges **472** positioned substantially perpendicular to the EL laminate lamp material **480** between pairs **450, 452** and **454, 456** of strips. The resulting slit laminate **482, 484** are each a coil of split electrode EL lamp construction which does not need scribing as described in connection with "raw" EL lamp material further produced as uncut laminate. Here the split-electrode EL lamp is pre-scribed as a result of the lamination procedure thus saving a processing step and eliminating sacrificial yield losses which are generated as a result of the scribing process. The slit laminates **482, 484** are coiled on take-up reels for future use.

Turning now to Fig. 12, a cross-sectional view of a finished split electrode EL lamp cut from a continuous roll of EL lamp material made in accordance with the present invention is shown schematically therein and generally designated **500**. Figure 13 is a plan view of the back of a finished EL lamp and is generally designated **510**. In the embodiments illustrated in Figs. 12 and 13, the scribe line, generally designated **502**, splits or cuts through the rear substrate into the EL lamp material a depth that goes through the polyester **202**, aluminum foil **204** and partially into the barium titanate layer **206**. As illustrated in Fig. 13, the scribe line **502** is substantially down the middle, that is, approximately the center, between the edges **504, 506** to define two substantially equal areas **508, 512**. The substantially equal areas **508, 512** cause the EL lamp to produce substantially equal illumination when power is applied to the EL lamp by means of connectors **514, 516**. The connectors **514, 516** are illustrated in Figs. 17 and 18. The connector **514** has at least one leg **518** extending from and integral to and in electrical and mechanical contact with a tab portion **520**, which has a surface **522** to which electrical connection or electrical contact is made. In the illustrated embodiment, the

connector **514** has two legs **518** extending substantially perpendicular from the plane of the tab **520**. The length **L** of the leg **518** is of sufficient length to extend through the thickness of the EL lamp material laminate such that the end portion **524** of the leg **518** can be bent over and crimped to hold the connector **514** in contact with the aluminum foil **204** and the EL lamp material laminate, as illustrated in Fig. 12. When the connector **514** is first inserted and crimped to hold the EL lamp material laminate, an electrical short circuit is created between the ITO layer **102** and the aluminum foil **204**. As illustrated in Fig. 12, the leg **518** of the connector **514** passes through the ITO layer **102** and creates an electrical short circuit between the connector **514** and the ITO in the region around the leg portion **526**. When electrical power is first supplied to the lamp, the ITO in the region around the leg portions **526** will vaporize to remove the electrical short circuit due to the electrical current that will attempt to flow through the ITO conductive path. Once the electrical short circuit is removed, the EL lamp will transmit light from the front electrode.

Figure 14 is a plan view of the back of a finished EL lamp made in accordance with the present invention and is generally designated **530**, wherein the scribe line, shown generally as **532**, splits the rear electrode of the EL lamp to create unequal surface areas **534, 536**. Connectors **514, 516** pass through the EL lamp material laminate and function as described in connection with Figs. 12 and 13. Since the rear electrode surface areas **534, 536** are unequal in surface area, the electrical current will divide substantially proportionate to the rear electrode surface area in a similar manner as a parallel resistor electric circuit. The voltage applied to the EL lamp via the connectors **514, 516** will divide substantially proportionate to the ratio of the two rear electrode surface areas in a similar manner as two capacitors in series in an electrical circuit. In an electrical circuit, a voltage divider is formed by two capacitors in series. If the capacitors are equal in value, the voltage will divide evenly across each of the capacitors. If the capacitors are not equal in value, the voltages will divide unequally with the smaller capacitor receiving the larger proportionate value. Likewise, the smaller surface electrode

area in the EL lamp will receive the higher proportionate value and will be brighter than the larger surface electrode area. It can be seen that locating the scribe line **532** at different locations along the rear electrode permits the production of special effect lighting; that is, lighter and darker areas relative to one another.

Turning now to Figs. 15 and 16, a parallel plate EL lamp is constructed from the EL lamp material made in accordance with the present invention, wherein dual scribe lines located along one marginal edge create a large surface area for illumination. A plan view of the parallel plate EL lamp is illustrated in Fig. 15 and is generally designated **540**. The parallel plate EL lamp **540** is shown with two scribe lines **542, 544** along one marginal edge region generally designated **546**. The scribe line **542**, as illustrated in Fig. 16, is of sufficient depth to pass through the polyester layer **202**, aluminum layer **204** and partially into the barium titanate layer **206**. The scribe line **544** cuts through the polyester layer **202**, aluminum layer **204**, barium titanate layer **206**, through the phosphor particles **106** in the phosphor monolayer, through the UV organic binder layer **104**, to the ITO layer **102**. A silver ink **450** floods the void left by the scribe line **544** to completely fill the void so that contact is made between the silver ink **450** and the ITO layer **102** in the region **452** at the end **454** of the scribe line **544** and the aluminum layer **550**. When power is supplied to the connectors **514, 516**, the rear electrode area **560** will have one polarity voltage applied and the ITO/phosphor UV binder electrode will have a second voltage polarity applied to it by means of the electrical connection made by the silver ink **450** extending through the EL laminate to the ITO layer **102**. The purpose and function of the connector **514** at the marginal edge area **546** is to provide a means of electrical connection to the EL lamp and to provide a mechanical and electrical mounting area for an external connection. The crimping of the legs **524** maintains the contact between the connector **514** and the laminate. The voltage is applied to the ITO layer **102** by means of the silver ink **450**. Since the scribe lines **542, 544** can be located very close to one edge **546**, the remaining surface area between the scribe line **542** and the edge **548** transmits light.

Referring now to Fig. 19, a plan view of an alternate embodiment of a finished parallel plate EL lamp having multiple dual scribe lines is illustrated therein and generally designated **570**. The parallel plate lamp of Fig. 19 is somewhat similar to the parallel plate lamp illustrated in Fig. 15 and includes connectors **514, 516, 528**. In the illustrated embodiment of Fig. 19, scribe lines **572, 574** are along one marginal end region **576**, wherein the scribe line **572** cuts through the polyester, and aluminum layers into the barium titanate layer as described above in connection with Fig. 16. The scribe line **574** cuts through the layers of the laminate to the surface of the ITO layer **102** as described above in connection with Fig. 16. The scribe line **574** is flooded with a conductive material, such as silver ink **578**, to provide connection to the ITO layer. Scribe lines **580, 582** are located along the marginal edge **584** opposite the marginal edge **576**. The scribe line **580** is likewise cut to a depth to penetrate the barium titanate layer and separate the aluminum foil and polyester layer as described above in connection with the scribe line **542** of Fig. 16. Likewise, the scribe line **582** is cut through the laminate from the rear electrode surface to the ITO surface layer **102** and is flooded with a conductive material, such as silver ink **586**, to provide an electrical connection from the connector **528** to the ITO layer **102**. The connector **516** provides an electrical connection to the aluminum foil rear electrode area **588**. The alternate embodiment illustrated in Fig. 19 allows the finished parallel plate EL lamp to be substantially larger with minimal variation in the light brightness across the front electrode surface.

Fig. 20 is a further alternate embodiment of a finished parallel plate EL lamp having dual scribe lines located along the marginal peripheral edge regions on all sides of the lamp to increase the maximum lamp size that can be made using a parallel plate construction with a minimal variation in brightness across the lamp. The finished parallel plate EL lamp is designated generally **590** and includes electrical connectors **592, 594**. A scribe line **596** is cut on all four sides through the layers to a depth to the ITO layer. The void created by the scribe line **596** is filled with a conductive material, such as a silver ink **598**, and functions as described above in connection with the description of Fig. 16. A second scribe line **600** is

substantially parallel to the scribe line **596** and splits the rear electrode as described above in connection with the scribe line **542** of Fig. 16. The electrical connectors **592, 594** function similarly and in a substantially identical manner as the connectors **514, 516** described and illustrated above. In the illustrated embodiment of Fig. 20, power is supplied to the connectors **592, 594** to light the area corresponding to the rear electrode area shown as **602**. As in the parallel plate embodiment illustrated in Fig. 19, the parallel plate EL lamp embodiment illustrated in Fig. 20 maximizes the lamp size that can be made with a parallel plate construction with a minimal variation in brightness across the lamp.

Turning now to Fig. 21, an array of rear electrodes made from multiple scribe lines is shown in plan view and generally designated **610**. As illustrated in Fig. 21, the rear electrode is scribed with multiple scribe lines **612, 614, 616, 618** to provide an array of rear electrode surface areas **620, 622, 624, 626, 628, 630, 632, 634**. Each rear electrode array is provided with an electrical connector **636** located along the marginal edge region, generally designated **638, 640**, respectively. An electrical conductor or cable **642** extends from each connector **636** for providing power to the EL lamp. The connector **636** is substantially identical in function and operation as described above in connection with the connector **514**. The isolated and individual rear electrode sections **620-634** are isolated from one another and must be activated or powered in pairs or multiple pairs to provide the desired special effect lighting. For example, applying power to the connector **636** of rear electrode section **622** and the connector **636** of the rear electrode section **632** will cause light to be transmitted from the front electrode under the regions corresponding to the areas **622, 632**. It can be seen that by powering individual pairs light will be transmitted through the front electrode corresponding to the rear electrode areas being powered. Special lighting effects, such as bar lighting, sequential lighting and random lighting, can be produced by controlling the voltage applied to the various segments in accordance with the desired lighting patterns.

A method and apparatus for the continuous manufacturing of EL lamp material and EL lamps made therefrom has been disclosed above in several

preferred embodiments for purposes of explanation rather than limitation. Further materials comprising the various layers of the finished EL lamp material laminate having the desired characteristics may be used without departing from the spirit and scope of the invention as understood by those skilled in the art of EL lamp manufacturing and production.